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**XLVII.** *Observations and Experiments upon animal Bodies, digested in a philosophical Analysis, or Inquiry into the Cause of voluntary muscular Motion ; by Charles-Morton, M. D. F. R. S.*

Read Dec. 5, 1751. **T**HE paper proceeds in the following order:

*The Problem*, or question proposed.

*Observations and Experiments*, illustrating the structure and use of the parts concerned.

*Two Lemma's*, with demonstrations concerning automatic or involuntary motion.

*Observations* proving, that the sensations, of which we take cognizance, are merely relative.

*Observations* proving, that the will has a power over sensation universally, to render it more or less acute.

*Solution*, or answer to the question, necessarily arising from the preceding facts.

*Some short scholia.*

*Problem.*

A muscle being given in its natural state, in a living animal body, it is asked how, or by what mechanical means, that muscle contracts, and is again relaxed, at the command of the will ?

*Observations illustrating the structure and use of the parts concerned.*

Every muscle of an animal body is observed to be an instrument composed of fibres or lesser muscles,

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which are joined together every-where, by one common membrane or substance, called from its appearance, cellular. This substance, when it arrives at the surface of the muscle, becomes uniform, and makes one intire sheath for the whole muscle, or bundle of fibres, and renders it distinct from others.

The constituent fibres in many muscles are observed to be partly fleshy, and partly tendinous; the one changing, or being continued, into the other, for the conveniency of insertion and motion. But the observation is universal, that the fleshy fibres alone contract in muscular motion, and that this contraction is always wave-like, or in alternate curls, from one extremity to the other of a given fibre.

We constantly observe, in every muscle, numerous arteries, veins, and nerves. These are generally distributed together, or in the same course, by means of the connecting cellular substance, into every point of the fleshy fibres. Injections, and the knife of the anatomist, have follow'd them a great way, and reason completes the distribution, since you can nowhere wound the flesh of a muscle, but it shall bleed, and witness a sense of pain.

Therefore there is a circulation of blood, throughout the whole fleshy substance of a muscle: and further the muscle feels in every part.

In a living animal, if you tie the artery and vein, which principally belong to a given muscle, that muscle is disabled from acting at the command of the will. Steno, a Danish anatomist of the last century, performed this experiment upon the descending aorta, and thereby took away the use of all the lower limbs (*vide Bergerum*, p. 296) at once, and restored them

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at pleasure. Late anatomists have tried it upon lesser vessels, with the same constant success. (Vide *Albini histor. muscul.* p. 19.)

In a living animal, if you tie the nerve, that supplies a given muscle, that muscle is disabled from acting at the command of the will. This experiment is distinctly mentioned by Galen in his treatise on the muscles, and is approved by the trials of later anatomists. (*Alb.* p. 19.)

From these two experiments it is clear, and generally agreed upon, that, in order to the performance of voluntary muscular motion, besides the particular structure, there is required an absolute freedom of the blood-vessels, and the nerves.

Muscular motion is observed to be voluntary, and involuntary. Of the first kind are almost all the muscles of an animal body; of the latter, the only complete instance is the heart. The first seems more complex than the latter, since, besides the motion, it implies an additional act of the will. Effects, that are less compounded, ought naturally to precede effects, that are more; these receiving light from the former, where both are homogeneous. For this reason, I have placed here two lemma's relating to automatic, or involuntary motion.

### *Lemma 1.*

The heart, in its natural state, in a living animal body, being given, its contraction proceeds solely from, or is mechanically caused by, the warm blood, flowing into and filling its fleshy substance in every part.

If this be denied, let the body of an animal be taken quickly after death, and let a warm mild fluid of any kind be injected gently into the heart, so as to fill it. When this is done, we shall see the heart quicken and contract, as in the life of the animal. This experiment was first distinctly mentioned by Peyer a Switzer (see a small treatise of his, printed anno 1682, at Amsterdam, and intituled, *Miraculum anatomicum in cordibus juscitatis*) and is now known to every anatomist. But if this effect is thus constantly produced soon after death, how much more, when the animal is alive? And if, by the introduction of any common fluid, with the bare addition of a warmth cognizable by our senses, how much more by the introduction of the living blood, an inimitable and wonderful fluid, and the immediate subject of the vital warmth?

If therefore it is granted, that we ought not to admit more causes of natural things than are real (and present for the occasion) and sufficient for explaining the appearances (*a*), and we must grant a rule, whose use is so obvious in the Newtonian, which is the philosophy of nature; we shall, I say, also grant, that the contraction of the heart, in its natural state; in a living animal body proceeds solely from, or is mechanically caused by, the warm blood, flowing into, and filling, its fleshy substance in every part. Which was to be proved.

*Corollary.*

The subsequent relaxation admits no difficulty: for if the blood is the immediate mechanical cause of the contraction, when the blood is removed, the effect ceases.

*Lemma*

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(*a*) Newton, R. 1.

A muscle of voluntary motion, in its natural state, in a living animal body, being given, it will contract by the introduction of a warm mild fluid, into its fleshy substance in every part.

If this be denied, let the body of an animal be taken quickly after death, and the crural artery be pierced, and a warm mild fluid be injected into it: we shall then see the muscles, to which the artery belongs, quicken and contract, as if the living animal moved them. This experiment was known to Mr. Cowper, and is confirmed by Albinus (see *Hist. Musc.* p. 21.)

But if this effect is constantly produced soon after death, how much more when the animal is alive?

Therefore a muscle of voluntary motion, in its natural state, in a living animal body, will contract, by the introduction of a warm mild fluid, into its fleshy substance, in every part: Which was to be proved.

But here it may be objected, with some appearance of reason, that there is a warm fluid, the living blood, in every part of the fleshy substance of all the muscles, during the life of the animals; and yet it is a fact, that no muscle of voluntary motion contracts, but at the command of the will, morbid cases excepted. This objection comes close to the original question, and however reasonable it may seem, will quickly vanish before some common observations concerning the objects of sense in general, and their manner of operating upon the different organs, so far as it universally agrees.

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We must first beg leave to make an easy postulat-  
um, *viz.* that the nerves are the immediate instru-  
ments of sensation, though they are differently or-  
ganized for the different senses.

*Observations, proving that the sensations of which we  
take cognizance are merely relative.*

It is a certain fact; that, in the several senses, the  
proper objects being suppose present, the sensation is  
intirely relative; or, in other words, that the presence  
of a powerful object always obliterates the present  
sensation of a weak object; and that the constant ha-  
bitual presence of any one object, in the same given  
degree, produces no sensation at all.

Thus we observe, that the light of the sun extin-  
guishes the light of the stars; a stronger taste covers a  
weaker; the sound of a drum drowns an ordinary  
human voice; itching is banished by smart and pain;  
a weak scent, by one that is strong; cold, or a less  
degree of warmth, by heat, or a greater degree of  
warmth; and universally, our daily experience de-  
monstrates to us, that every organ of sense, made  
familiar to a given degree of its object, affords no  
manner of sensation of the object in the given degree.

Thus it fares with the warm blood, which has  
constantly flowed through the whole minute sub-  
stance of every muscle of voluntary motion in an animal  
body, from the time of their formation, or unfold-  
ing in the womb. And it is highly probable, that  
the quickening of the child in a woman is no other  
than the completion of that state, in which the blood  
begins freely to flow through, and to affect the in-  
struments of voluntary motion; and till it becomes  
familiar

familiar to them, produces those frequent shudders, or general muscular contractions in the whole frame of the foetus, which for a fortnight or more are the constant signs, that it has now obtained an animal life.

And here arises an apparent difference, though it will be found the greatest uniformity, between the muscles of voluntary and those of involuntary motion; and namely the heart; which being appointed to protrude the vital fluids during the life of an animal, has a short alternate remission of its contracting cause; and is thereby render'd capable of admitting a constant and necessary supply of labour and stimulus together, without any force, or contradiction, to the natural order of the whole.

It follows undeniably from what has been said, that if we can prove, that a given muscle of voluntary motion, does really feel an increase of the familiar warmth of its contained blood, or an equivalent, to rise and fall instantly at the command of the will, we shall then duly account for the subsequent motion. Or, more particularly, if we can prove, that the will has a direct power of heightening, increasing, and rendering more acute, the sense of any nerve, distributed to a given muscle, the same familiar positive degree of warmth in the contained blood will, to this more acute sense, appear to be proportionably heightened and increased, and the muscle (by lemma 2) will instantly contract, and continue in that state during the action of the will; allowing for a small feebleness, that will gradually arise from the gradual exclusion of the contracting cause, and from the blunting of this more acute, and, as it were, new sensation; which yet, as we see, may  
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be proportionably compensated, by the will, for a time, even to the destruction of the nerve, the blood-vessels, and indeed the whole organ, by a mortification, which has been known to succeed a long muscular contraction.

*Observations, proving, that the will hath a direct power of rendering more acute the sensations of the nerves universally.*

We know from daily experience, that the will hath a power over all the organs of sense, to heighten, or render acute, and again to relax them, their proper objects, in a reasonable degree, being supposed present. And the same experience teaches us, that this power is greater or less, according to the more or less frequent use and exercise that is made of it. For it is obvious to every one, that any sound man is able to feel, to taste, to smell, to hear, and to see, more accurately when he pleases. And it is equally obvious and certain, that any one of these five senses, being exercised, with an uncommon degree of attention and industry, either from choice, or from necessity, arrives at an uncommon degree of accuracy, and perfection. Indeed it is intirely from use and exercise, that a child learns to distinguish at all between the several objects of a given sense, or, which are the same, between the several degrees, or modes, of its proper object.

All these particulars, being demonstrably true of every sense, that we can directly examine, the inference is very fair to the single sense (*Lem. 2.*) that we cannot directly examine; and, in truth, the induction in this case, is but one step below a complete experimental demonstration.

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It appears therefore, that the will hath a direct power of heightening, increasing, and rendering more acute, the sense or feeling of a given nerve, dispersed throughout the whole contracting substance of a given muscle, with all its gradations of accuracy and perfection. by repeated use and exercise.

*Solution, or answer to the problem.*

It follows therefore, that, a muscle being given, in its natural state, in a living animal body, the blood, which is present in every part of its contracting substance, and which, in effect, to the sense of the given muscle, (which is occasionally render'd more acute) puts on an increased heat, and again lays it down at the command of the will, is the immediate mechanical cause, by which the muscle does instantly contract, and is again relaxed, at the command of the will.

Therefore, a full solution is given to the question proposed : which was to be done.

*Corollary 1.*

Hence it appears, that muscular voluntary motion is performed merely as a sensation (*a*), extremely acute, and under the nicest management of the will : which explains its velocity in a great measure.

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*Corol.*

(a) Hartley *Conjecturae de sensu*, &c.

Hence it appears, that the Galenic distinction of nerves, into nerves of sensation and nerves of motion, which greatly puzzles physiology, has no real foundation in an animal body.

*A short scholium.*

The solution, that is given to the problem, may be assumed in a philosophical synthesis, and the various appearances may thence be announced, as well in natural as in morbid cases ; which again may be subjected to a strict examination. Some trial has been made of this, and a surprising agreement found : but the detail must be omitted. In the course of this inquiry, every foreign disquisition is industriously avoided, and such at this time would be a further question, Why blood, in a certain, or apparent, degree of heat, contracts a muscular fibre ?

The business of natural philosophy is, to observe, and to note down facts, that are constant ; and singling out those that are similar, to collect their proper universal, by a fair and regular induction ; and to acquiesce in this, till a new collection of constant and similar facts affords an higher universal, and leads nearer the first cause.

October 16, 1751.